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FORM PTO-1390 (REV 5-93) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER **225/50746**

U S APPLICATION NO (if known, see 37 CFR 1.5) 10/018224

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP00/04521	**19 May 2000**	**18 June 1999**

TITLE OF INVENTION
ELECTRICALLY HEATABLE GLOW PLUG OR GLOW ROD FOR INTERNAL COMBUSTION ENGINES AND METHOD OF MAKING SAME

APPLICANT(S) FOR DO/EOU.S. Patent No.
Klaus GESSNER and Roland KLAK

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1.	X	This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.		
2.		This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371		
3.		This express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay Examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).		
4.	X	A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.		
5.	X	A copy of the International Application as filed (35 U.S.C. 371(c)(2)).		
		a.		is transmitted herewith (required only if not transmitted by the International Bureau).
		b.	X	has been transmitted by the International Bureau **& PCT/IB/308 & 1st page of the International Publication**
		c.		is not required, as the application was filed in the United States Receiving Office (RO/US)
6.	X	A translation of the International Application into English (35 U.S.C. 371(c)(2)).		
7.		Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))		
		a.		are transmitted herewith (required only if not transmitted by the International Bureau).
		b.		have been transmitted by the International Bureau.
		c.		have not been made; however, the time limit for making such amendments has NOT expired.
		d.		have not been made and will not be made.
8.		A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).		
9.	X	An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) – **Unexecuted**		
10.		A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).		

Item 11. to 16. below concern other document(s) or information included:

11.	X	An Information Disclosure Statement under 37 CFR 1.97 and 1.98 **& Form PTO-1449 with 4 references**
12.		An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13.	X	A FIRST preliminary amendment **& an Abstract of the Disclosure**
		A SECOND or SUBSEQUENT preliminary amendment.
14.	X	A substitute specification and marked-up copy thereof.
15.		A change of power of attorney and/or address letter.
16.		Other items or information:

a. **2 Sheets of Drawings showing Figures 1-3**
b.
c.

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 10/018224	INTERNATIONAL APPLICATION NO PCT/EP00/04521	ATTORNEY'S DOCKET NUMBER 225/50746	
17. [X] The following fees are submitted:		CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO	$ 890.00	$ 890.00	
International preliminary examination fee paid to USPTO (37 CFR 1.482)	$ 710.00		
No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)	$ 740.00		
Neither international preliminary examination fee (37 CFR 1.482) nor International search fee (37CFR 1.445(a)(2) paid to USPTO	$ 1040.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)	$ 100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =		$ 890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).		$ 130.00	

Claims	Number Filed	Number Extra	Rate		
Total Claims	12 - 20 =	0	X $18.00	$	
Independent Claims	4 - 3 =	1	X $84.00	$ 84.00	
Multiple dependent claims(s) (if applicable)			+ $280.00	$	
TOTAL OF ABOVE CALCULATIONS=				$1,104.00	
Applicant claims Small Entity Status (See 37 CFR §1.27) [ ] yes [ ] no. Reduction by 1/2 for filing by small entity, if applicable.				$	
SUBTOTAL =				$1,104.00	
Processing fee of $130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$	
TOTAL NATIONAL FEE =				$1,104.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28,3.31). $40.00 per property +				$	
TOTAL FEE ENCLOSED =				$1,104.00	
				Amount to be: refunded	$
				Charged	$

a. [X] One check in the amount of $1,104.00 for the filing fee is enclosed.

b. [ ] Please charge my Deposit Account No. ______ in the amount of $______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees, which may be required, or credit any overpayment to Deposit Account No. 05-1323 . A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:	[signature] 45,370
Crowell & Moring, L.L.P.	SIGNATURE
P.O. Box 14300	James F. McKeown
Washington, D.C. 20044-4300	NAME
Tel. No. (202) 624-2500	25,406
Fax No. (202) 628-8844	REGISTRATION NUMBER
	December 18, 2001
	DATE

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Attorney Docket: 225/50746
CAM #: 95309.275
PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: KLAUS GESSNER ET AL

Application No.: PCT/EP00/04521

Filed: December 18, 2001

Title: ELECTRICALLY HEATABLE GLOW PLUG OR GLOW ROD FOR INTERNAL COMBUSTION ENGINES AND METHOD OF MAKING SAME

PRELIMINARY AMENDMENT

Box PCT
Commissioner for Patents
Washington, D.C. 20231

December 18, 2001

Sir:

Prior to the examination and calculation of fees, please preliminarily amend the above-identified application as follows:

IN THE TITLE

Please change "ELECTRICALLY HEATABLE GLOW PLUG OR GLOW ROD FOR INTERNAL COMBUSTION ENGINES" to --ELECTRICALLY HEATABLE GLOW PLUG OR GLOW ROD FOR INTERNAL COMBUSTION ENGINES AND METHOD OF MAKING SAME--.

IN THE SPECIFICATION

Attached are a Substitute Specification, a marked-up copy of the original specification, and a translation of the application from German.

IN THE CLAIMS

Please cancel Claims 1-4 without prejudice. Please add new Claims 5-16, as follows:

5. (New) Electrically heatable glow plug or glow rod for internal combustion engines, having a corrosion-resistant glow pipe which is closed at the end and contains a filling of electrically non-conductive, compacted powder in which an electrically conductive coil is embedded, wherein the electrically conductive coil is surface-hardened.

6. (New) Glow plug or glow rod according to Claim 5, wherein at least a heating coil is surface-hardened.

7. (New) Glow plug or glow rod according to Claim 5, wherein the electrically conductive coil (8, 9) is surface-hardened, at least over part of the longitudinal extent, by a diffusion treatment.

8. (New) Glow plug or glow rod according to Claim 7, wherein a hard diffusion zone of the electrically conductive coil has a depth of approximately 5 to 10 μm.

9. (New) Glow plug or glow rod according to Claim 7, wherein the diffusion treatment is nitriding.

10. (New) An electrically heatable heater for internal combustion engines, comprising:

a corrosion-resistant glow pipe which is closed at an end,

electrically non-conductive, compacted powder filling contained within the glow pipe, and

an electrically conductive coil which is embedded within the filling,

wherein at least a portion of the electrically conductive coil is surface-hardened.

11. (New) A electrically heatable heater according to Claim 10, wherein the surface-hardened portion is at least a heating coil.

12. (New) An electrically heatable heater according to Claim 11, wherein the surface hardening is by way of a diffusion treatment.

13. (New) An electrically conductive coil for a glow plug or glow rod in an internal combustion engine having a corrosion-resistant glow pipe closed at one end and containing a filling of electrically non-conductive, compacted powder, the conductive coil is operatively embedded in said filling and surface-hardened.

14. (New) A method of making an electrically heatable glow plug or glow rod for an internal combustion engine, comprising:

surface-hardening at least a portion of an electrically conductive coil,

positioning the conductive coil in a corrosion-resistant glow pipe,

embedding the conductive coil in an electrically non-conductive powder filling within the glow pipe,

compacting said powder filling, and

closing an end of the glow pipe.

15. (New) A method of making an electrically heatable glow plug or glow rod for an internal combustion engine comprising surface-hardening at least a portion of an electrically conductive coil.

16. (New) A method according to Claim 15, wherein the conductive coil is operatively embedded in an electrically non-conductive compacted powder filling within a glow pipe.

IN THE ABSTRACT

Please cancel the Abstract in its entirety and substitute the attached Abstract of the Disclosure submitted herewith on a separate, unnumbered sheet.

REMARKS

It is respectfully requested that the above amendments be entered prior to the examination of the application and the calculation of the application fee.

If there are any questions regarding this amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #225/50746).

Respectfully submitted,

James F. McKeown
Registration No. 25,406
William G. Ackerman
Registration No. 45,320

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JFM:WGA:sbh

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ABSTRACT OF THE DISCLOSURE

An electrically heatable glow plug or a glow rod for internal combustion engines. The glow plug has a corrosion-resistant glow pipe which is closed at the end and contains a filling of electrically non-conductive, compacted powder in which an electrically conductive coil is embedded. In order to improve the glow plug or the glow rod with respect to a longer service life for the heating coil, the electrically conductive coil is surface-hardened, at least over part of its longitudinal extent, preferably in the region of the heating coil. In particular, it is nitride-hardened by a diffusion treatment. As a result, the coil can withstand the mechanical stress during the compaction process without being damaged at the outset.

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Clean Copy of Substitute Specification

ELECTRICALLY HEATABLE GLOW PLUG OR GLOW ROD FOR INTERNAL COMBUSTION ENGINES AND METHOD OF MAKING SAME

BACKGROUND AND SUMMARY OF THE INVENTION

[0001] The invention is based on an electrically heatable glow plug or a glow rod for internal combustion engines, having a corrosion-resistant glow pipe which is closed at the end and contains a filling of electrically non-conductive, compacted powder in which an electrically conductive coil is embedded, as known, for example, from European Patent Document EP 450 185 B1 and corresponding U.S. Patent No. 5,130,517.

[0002] Glow plugs are used in the combustion chamber in diesel engines for preheating purposes during cold starting or - in the form of a glow rod in the induction passage - for preheating the induction air. The glow plug or the glow rod comprises a corrosion-free, metallic casing, a heating and regulating coil and an electrically insulating, compacted powder filling. In the heating region, the heating and regulating coil consists of ferritic steel onto which a pure nickel wire is welded as a regulating resistor.

[0003] During operation, the material of the heating coil is subject to a thermal and chemical influence which may adversely affect the service life of the glow plug. These influences at least constitute essential parameters with regard to the service life of the glow plug. On account of the high operating temperatures of the heating coil and, as before, there still being oxygen in the

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compacted powder filling, the heating coil is subject to creeping corrosion. In specific terms, this may firstly be intercrystalline corrosion which is furthered by the growth of crystals and the tendency to form large grains in ferritic heat conductors. Secondly, at high temperatures corrosion may occur on the free surface of the heating coil and may therefore lead to weakening of the heating-wire cross section.

[0004] Magnesium oxide is generally used as the powder filling. In order to minimize the atmospheric oxygen contained in the pores of the powder filling, the powder is very intensively compacted by the filled metal casing being upset from the outside by a concentrically acting striking tool and thereby being reduced in diameter. The powder filling is compacted particularly intensively in the region of the heating-rod tip by the metal casing being upset conically there.

[0005] The object of the invention is to improve a glow plug based on the generic type in respect of a longer service life for the heating coil.

[0006] Taking the glow plug based on the generic type as the starting point, this object is achieved according to the invention by the electrically conductive coil being surface-hardened . This is because it has been found that, during the compaction of the powder filling, the radial upsetting of the casing pipe also causes severe mechanical stress on the wire of the heating coil and on the wire of the regulating coil and in the process causes said wire to be unintentionally damaged at the outset, for example due to notches, depressions or the like, i.e. causes its cross section to be constricted locally. On account of the increase in hardness of the coil on its surface, in particular by nitriding, the coil is able to

withstand the mechanical stress during compaction of the powder filling without being significantly damaged at the outset.

[0007] Expedient refinements of the invention can be gathered from the subclaims; the invention is also explained in more detail below with reference to an exemplary embodiment which is illustrated in the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 shows a longitudinal section through a glow plug,

[0009] Fig. 2 shows an enlarged illustration of the detail II from Figure 1, and

[0010] Fig. 3 shows a cross section through a conventional glow plug in the region of the detail II where the surface of the coil has been damaged at the outset by the mechanical stress during compaction of the powder filling.

DETAILED DESCRIPTION OF THE DRAWINGS

[0011] In diesel engines, glow plugs are used in the combustion chamber for preheating during cold starting or - as a rod-shaped flame glow plug or flame system in the air inlet passage - for preheating the air. The exemplary embodiment of a glow plug which is illustrated in Figure 1 has a glow pipe 5 which is secured in a plug body 1 and is connected thereto in an electrically conductive manner. The casing of the glow pipe generally is made of a nickel-rich iron alloy or of a corrosion-free alloy based on nickel, for example Inconel 601, and is, as a rule, electrically connected as an earth pole, i.e. negatively. This electric earth connection comes about via the screw-in thread 7 and/or by the cone 7a at the lower end of the plug body 1.

[0012] A heating coil 8 having a regulating coil 9 which is welded to it via a connecting weld 11, and an electrically insulating, compacted powder filling 10 are arranged in the glow pipe. This powder filling has a number of functions, particularly in the compacted state. First, the powder filling ensures that the heating coil (8) and regulating coil (9) are accommodated and fixed in position within the glow pipe and are held in an electrically insulated manner. The compacted powder means that the heat produced in the heating coil 8 is inevitably passed on as readily as possible to the casing of the glow pipe. In addition, the compressing of the powder is intended to eliminate to the greatest possible extent any air pockets, in particular a certain amount of residual oxygen. This requires a particularly intensive compaction of the powder, particularly in the region of the heating coil 8.

[0013] In the heating region (heating coil 8), the heating and regulating coil 8, 9 are made of a ferritic steel, for example of an iron-chromium-aluminum alloy having 17 to 22% chromium and 3 to 7% aluminum. A frequently used alloy is Kantal AF CrAl225. A coiled wire (regulating coil 9) made of pure nickel, which has the function of a regulating resistor, is welded (connecting weld 11) onto a heating coil of this type. The heating coil 8 is connected to the glow pipe in the tip of the glow pipe via a sealing weld 12.

[0014] The other end of the regulating coil 9 is connected to a connecting bolt 2 which is embedded in an insulating washer 4, is electrically insulated and is led out of the plug body 1 in a sealed manner via a seal 6. The connecting bolt is connected via a nut 3, which brings a cable lug securely into contact with the connecting bolt, to the positive pole of a current source. In addition, the

connecting bolt 2 is sealed at the upper, open end of the glow pipe by a soft, insulating seal 6' which is intended to reliably prevent atmospheric oxygen from penetrating into the compressed powder filling.

[0015] In general, magnesium oxide is used as the powder filling 10. In order to compact the powder filling - as described, the filled glow pipe is upset radially from the outside by a concentrically acting striking tool and is thereby reduced in diameter, it also being possible for a conical profile to be achieved. The powder filling is particularly intensively compacted especially in the region of the glow-pipe tip by the metal casing there being upset radially in a particularly severe manner.

[0016] On account of the intense compaction of the powder filling, the entire coil 8, 9, but in particular the heating coil 8, is severely stressed mechanically. During the radial upsetting of the glow pipe 5 not only is its casing plastically deformed, but so too are the coils 8 and 9 mounted in it. The compacting and compacted powder filling 10 also transmits actions of force from the striking tools acting from the outside isostatically to the turns of the heating and regulating coils 8 and 9 and reduces the diameters (d) thereof to an appropriate extent during this process. Since, however, the powder filling is not completely homogeneous, but is subject to certain unevennesses, the forces exerted on the coils via the powder filling differ in size locally in accordance with the dispersion of the powder density.

[0017] In the case of untreated coils, this leads to a locally differing plastic upsetting of the coils. The differing upsetting for its part causes a stochastically pitted surface of the coils 8', as is shown in Figure 3 using the example of a

conventional design of a glow plug together with an untreated coil 8'. Even when new, this coil has a pitted surface 15 after compaction of the powder. According to the findings of the invention, a certain amount of damage from the outset is to be found in this surface pitting. This is because stochastic pitting of this type may result in local cross-sectional constrictions of the conductor cross section of the coil. This local cross-sectional constriction in turn leads to a local increase in the electrical resistance and therefore to a locally more severe heating of the coil during operation. This means that the thermal and chemical aging processes progress more rapidly at this point, because of the higher temperature level, than at other points. Such a constriction, which is initially only small and is caused by pitting, of the conductor cross section of the coil can therefore be a determining factor in the service life, i.e. can be a factor shortening the service life.

[0018] The invention intends to increase the service life of the coils, in particular the heating coil 8 which is particularly severely stressed mechanically during compaction and is also particularly severely stressed thermally during operation. In order to increase the service life, according to the invention the electrically conductive coils 8, 9 but at least the heating coil 8 which is particularly at risk, are surface-hardened. In specific terms, a diffusion treatment, such as nitriding, is advantageously recommended, said treatment leading, through the formation of nitride in the diffusion zone, to an increase in the hardness, and as a result of the diffusion processes produces a gradual transition from the hardened edge zone to the soft core. This diffusion zone 13 of

the coils 8, 9 expediently has a depth t of approximately 5 to 10 μm as shown in Figure 2.

[0019] Although the coils are hardened merely in an edge layer 13 near to the surface, they nonetheless remain plastically deformable as a whole. On the other hand, pronounced pitting of the wire surface during radial compaction of the powder filling is avoided by the hardening of the edge layer. Even after the compaction of the powder filling, the coils have a smooth surface 14. As a result, mechanical damage at the outset to the conductor wire is avoided. The consequence is a longer service-life expectation for the conductor and therefore for the entire glow plug.

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Clean Copy of Substitute Specification

ELECTRICALLY HEATABLE GLOW PLUG OR GLOW ROD FOR INTERNAL COMBUSTION ENGINES AND METHOD OF MAKING SAME

BACKGROUND AND SUMMARY OF THE INVENTION

[0001] The invention is based on an electrically heatable glow plug or a glow rod for internal combustion engines, having a corrosion-resistant glow pipe which is closed at the end and contains a filling of electrically non-conductive, compacted powder in which an electrically conductive coil is embedded, as known, for example, from European Patent Document EP 450 185 B1 and corresponding U.S. Patent No. 5,130,517.

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[0003] During operation, the material of the heating coil is subject to a thermal and chemical influence which may adversely affect the service life of the glow plug. These influences at least constitute essential parameters with regard to the service life of the glow plug. On account of the high operating temperatures of the heating coil and, as before, there still being oxygen in the

compacted powder filling, the heating coil is subject to creeping corrosion. In specific terms, this may firstly be intercrystalline corrosion which is furthered by the growth of crystals and the tendency to form large grains in ferritic heat conductors. Secondly, at high temperatures corrosion may occur on the free surface of the heating coil and may therefore lead to weakening of the heating-wire cross section.

[0004] Magnesium oxide is generally used as the powder filling. In order to minimize the atmospheric oxygen contained in the pores of the powder filling, the powder is very intensively compacted by the filled metal casing being upset from the outside by a concentrically acting striking tool and thereby being reduced in diameter. The powder filling is compacted particularly intensively in the region of the heating-rod tip by the metal casing being upset conically there.

[0005] The object of the invention is to improve a glow plug based on the generic type in respect of a longer service life for the heating coil.

[0006] Taking the glow plug based on the generic type as the starting point, this object is achieved according to the invention by the electrically conductive coil being surface-hardened . This is because it has been found that, during the compaction of the powder filling, the radial upsetting of the casing pipe also causes severe mechanical stress on the wire of the heating coil and on the wire of the regulating coil and in the process causes said wire to be unintentionally damaged at the outset, for example due to notches, depressions or the like, i.e. causes its cross section to be constricted locally. On account of the increase in hardness of the coil on its surface, in particular by nitriding, the coil is able to

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[0014] The other end of the regulating coil 9 is connected to a connecting bolt 2 which is embedded in an insulating washer 4, is electrically insulated and is led out of the plug body 1 in a sealed manner via a seal 6. The connecting bolt is connected via a nut 3, which brings a cable lug securely into contact with the connecting bolt, to the positive pole of a current source. In addition, the

connecting bolt 2 is sealed at the upper, open end of the glow pipe by a soft, insulating seal 6' which is intended to reliably prevent atmospheric oxygen from penetrating into the compressed powder filling.

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2/ PATS

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ELECTRICALLY HEATABLE GLOW PLUG OR GLOW ROD FOR INTERNAL COMBUSTION ENGINES AND METHOD OF MAKING SAME

<u>BACKGROUND AND SUMMARY OF THE INVENTION</u>

The invention is based on an electrically heatable glow plug or a glow rod for internal combustion engines [according to the precharacterizing clause of Claim 1], <u>having a corrosion-resistant glow pipe which is closed at the end and contains a filling of electrically non-conductive, compacted powder in which an electrically conductive coil is embedded,</u> [such as emerges] as known, for example, from <u>European Patent Document</u> EP 450 185 B1 <u>and corresponding U.S. Patent No. 5,130,517</u>.

Glow plugs are used in the combustion chamber in diesel engines for preheating purposes during cold starting or - in the form of a glow rod in the induction passage - for preheating the induction air. The glow plug or the glow rod comprises a corrosion-free, metallic casing, a heating and regulating coil and an electrically insulating, compacted powder filling. In the heating region, the heating and regulating coil consists of ferritic steel onto which a pure nickel wire is welded as a regulating resistor.

During operation, the material of the heating coil is subject to a thermal and chemical influence which may adversely affect the service life of the glow plug. These influences at least constitute essential parameters with regard to the service life of the glow plug. On account of the high operating temperatures

of the heating coil and, as before, there still being oxygen in the compacted powder filling, the heating coil is subject to creeping corrosion. In specific terms, this may firstly be intercrystalline corrosion which is furthered by the growth of crystals and the tendency to form large grains in ferritic heat conductors. Secondly, at high temperatures corrosion may occur on the free surface of the heating coil and may therefore lead to weakening of the heating-wire cross section.

Magnesium oxide is generally used as the powder filling. In order to minimize the atmospheric oxygen contained in the pores of the powder filling, the powder is very intensively compacted by the filled metal casing being upset from the outside by a concentrically acting striking tool and thereby being reduced in diameter. The powder filling is compacted particularly intensively in the region of the heating-rod tip by the metal casing being upset conically there.

The object of the invention is to improve a glow plug based on the generic type in respect of a longer service life for the heating coil.

Taking the glow plug based on the generic type as the starting point, this object is achieved according to the invention by the [characterizing features of Claim 1] electrically conductive coil being surface-hardened . This is because it has been found that, during the compaction of the powder filling, the radial upsetting of the casing pipe also causes severe mechanical stress on the wire of the heating coil and on the wire of the regulating coil and in the process causes said wire to be unintentionally damaged at the outset, for example due to notches, depressions or the like, i.e. causes its cross section to be constricted locally. On account of the increase in hardness of the coil on its surface, in

particular by nitriding, the coil is able to withstand the mechanical stress during compaction of the powder filling without being significantly damaged at the outset.

Expedient refinements of the invention can be gathered from the subclaims; the invention is also explained in more detail below with reference to an exemplary embodiment which is illustrated in the [drawing, in which:] <u>drawings.</u>

<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

Fig. 1 shows a longitudinal section through a glow plug,

Fig. 2 shows an enlarged illustration of the detail II from Figure 1, and

Fig. 3 shows a cross section through a conventional glow plug in the region of the detail II where the surface of the coil has been damaged at the outset by the mechanical stress during compaction of the powder filling.

<u>DETAILED DESCRIPTION OF THE DRAWINGS</u>

In diesel engines, glow plugs are used in the combustion chamber for preheating during cold starting or - as a rod-shaped flame glow plug or flame system in the air inlet passage - for preheating the air. The exemplary embodiment of a glow plug which is illustrated in Figure 1 has a glow pipe 5 which is secured in a plug body 1 and is connected thereto in an electrically conductive manner. The casing of the glow pipe generally [consists] <u>is made</u> of a nickel-rich iron alloy or of a corrosion-free alloy based on nickel, for example Inconel 601, and is<u>,</u> as a rule<u>,</u> electrically connected as an earth pole, i.e.

negatively. This electric earth connection comes about via the screw-in thread 7 and/or by the cone 7a at the lower end of the plug body 1.

A heating coil 8 having a regulating coil 9 which is welded to it via a connecting weld 11, and an electrically insulating, compacted powder filling 10 are arranged in the glow pipe. This powder filling has a number of functions, particularly in the compacted state[: first of all, it]. First, the powder filling ensures that the heating coil (8) and regulating coil (9) are accommodated and fixed in position within the glow pipe and are held in an electrically insulated manner. The compacted powder means that the heat produced in the heating coil 8 is inevitably passed on as readily as possible to the casing of the glow pipe. In addition, the compressing of the powder is intended to eliminate to the greatest possible extent any air pockets, in particular a certain amount of residual oxygen. This requires a particularly intensive compaction of the powder, particularly in the region of the heating coil 8.

In the heating region (heating coil 8), the heating and regulating coil 8, 9 [consists] are made of a ferritic steel, for example of an iron-chromium-[aluminium] aluminum alloy having 17 to 22% chromium and 3 to 7% [aluminium; a] aluminum. A frequently used alloy is Kantal AF CrAl225. A coiled wire (regulating coil 9) made of pure nickel, which has the function of a regulating resistor, is welded (connecting weld 11) onto a heating coil of this type. The heating coil 8 is connected to the glow pipe in the tip of the glow pipe via a sealing weld 12.

The other end of the regulating coil 9 is connected to a connecting bolt 2 which is embedded in an insulating washer 4, is electrically insulated and is led

out of the plug body 1 in a sealed manner via a seal 6. The connecting bolt is connected via a nut 3, which brings a cable lug securely into contact with the connecting bolt, to the [plus] positive pole of a current source. In addition, the connecting bolt 2 is sealed at the upper, open end of the glow pipe by a soft, insulating seal 6' which is intended to reliably prevent atmospheric oxygen from penetrating into the compressed powder filling.

In general, magnesium oxide is used as the powder filling 10. In order to compact the powder filling - as described, the filled glow pipe is upset radially from the outside by a concentrically acting striking tool and is thereby reduced in diameter, it also being possible for a conical profile to be achieved. The powder filling is particularly intensively compacted especially in the region of the glow-pipe tip by the metal casing there being upset radially in a particularly severe manner.

On account of the intense compaction of the powder filling, the entire coil 8, 9, but in particular the heating coil 8, is severely stressed mechanically. During the radial upsetting of the glow pipe 5 not only is its casing plastically deformed, but so too are the coils 8 and 9 mounted in it. The compacting and compacted powder filling 10 also transmits actions of force from the striking tools acting from the outside isostatically to the turns of the heating and regulating coils 8 and 9 and reduces the diameters (d) thereof to an appropriate extent during this process. Since, however, the powder filling is not completely homogeneous, but is subject to certain unevennesses, the forces exerted on the coils via the powder filling differ in size locally in accordance with the dispersion of the powder density.

In the case of untreated coils, this leads to a locally differing plastic upsetting of the coils. The differing upsetting for its part causes a stochastically pitted surface of the coils 8', as is shown in Figure 3 using the example of a conventional design of a glow plug together with an untreated coil 8'. Even when new, this coil has a pitted surface 15 after compaction of the powder. According to the findings of the invention, a certain amount of damage from the outset is to be found in this surface pitting. This is because stochastic pitting of this type may result in local cross-sectional constrictions of the conductor cross section of the coil. This local cross-sectional constriction in turn leads to a local increase in the electrical resistance and therefore to a locally more severe heating of the coil during operation. This means that the thermal and chemical [ageing] <u>aging</u> processes progress more rapidly at this point, because of the higher temperature level, than at other points. Such a constriction, which is initially only small and is caused by pitting, of the conductor cross section of the coil can therefore be a determining factor in the service life, i.e. can be a factor shortening the service life.

The invention intends to increase the service life of the coils, in particular the heating coil 8 which is particularly severely stressed mechanically during compaction and is also particularly severely stressed thermally during operation. In order to increase the service life, according to the invention the electrically conductive coils 8, 9 but at least the heating coil 8 which is particularly at risk, are surface-hardened. In specific terms, a diffusion treatment, such as nitriding, is advantageously recommended, said treatment leading, through the formation of nitride in the diffusion zone, to an increase in the hardness, and as a result of

the diffusion processes produces a gradual transition from the hardened edge zone to the soft core. This diffusion zone 13 of the coils 8, 9 expediently has a depth t of approximately 5 to 10 μm as shown in Figure 2.

Although the coils are hardened merely in an edge layer 13 near to the surface, they nonetheless remain plastically deformable as a whole. On the other hand, pronounced pitting of the wire surface during radial compaction of the powder filling is avoided by the hardening of the edge layer. Even after the compaction of the powder filling, the coils have a smooth surface 14. As a result, mechanical damage at the outset to the conductor wire is avoided. The consequence is a longer service-life expectation for the conductor and therefore for the entire glow plug.

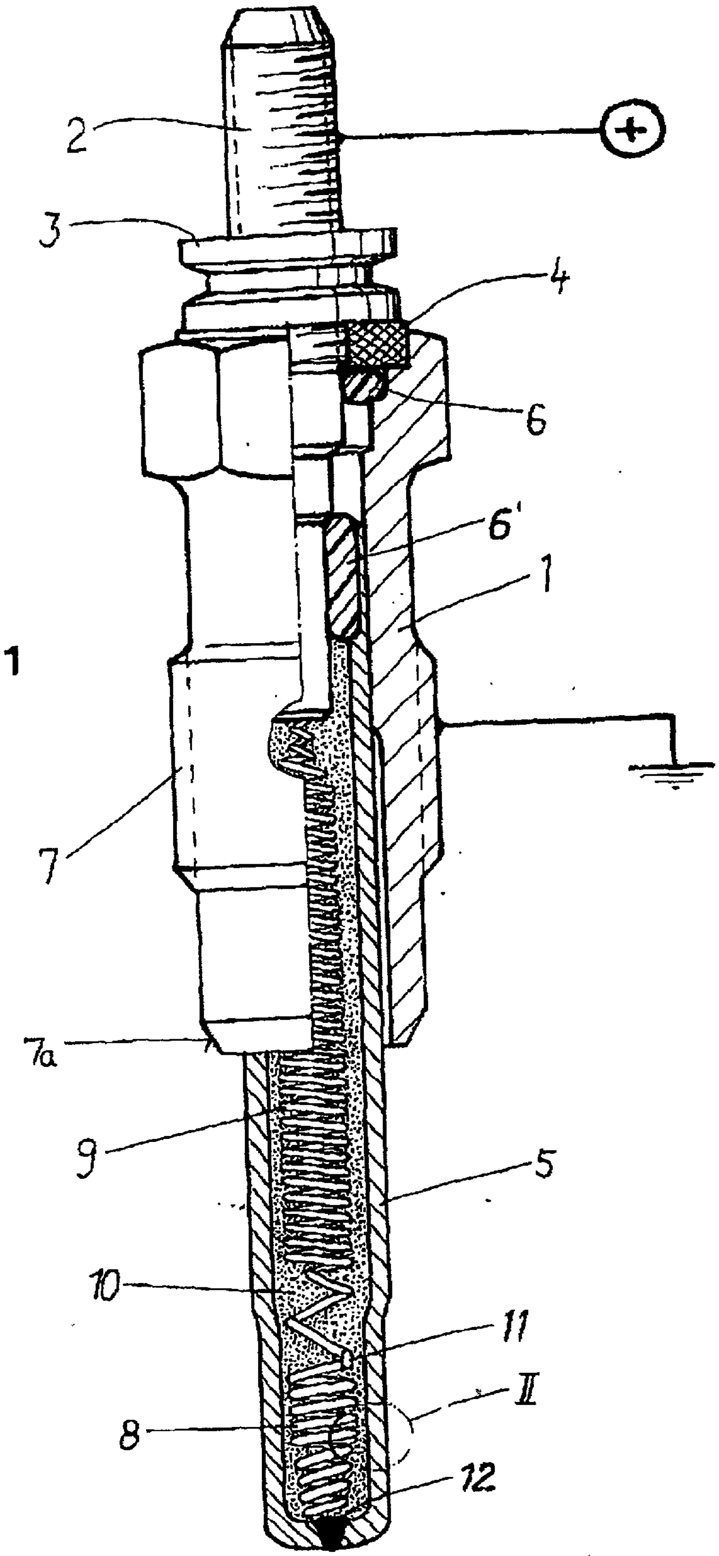


Fig. 1

Fig. 2

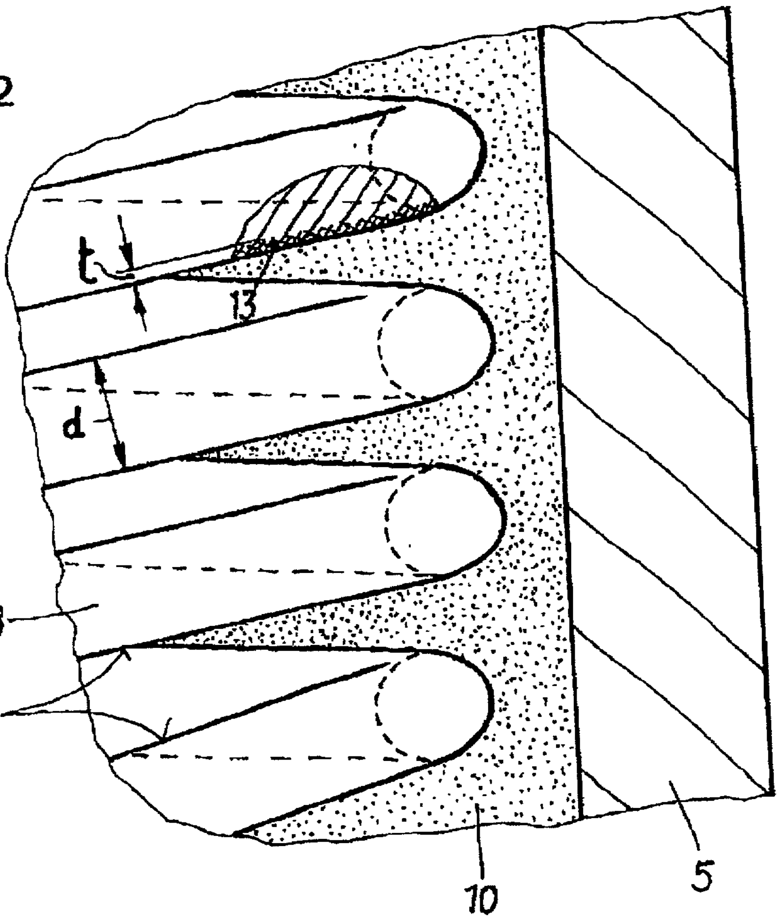
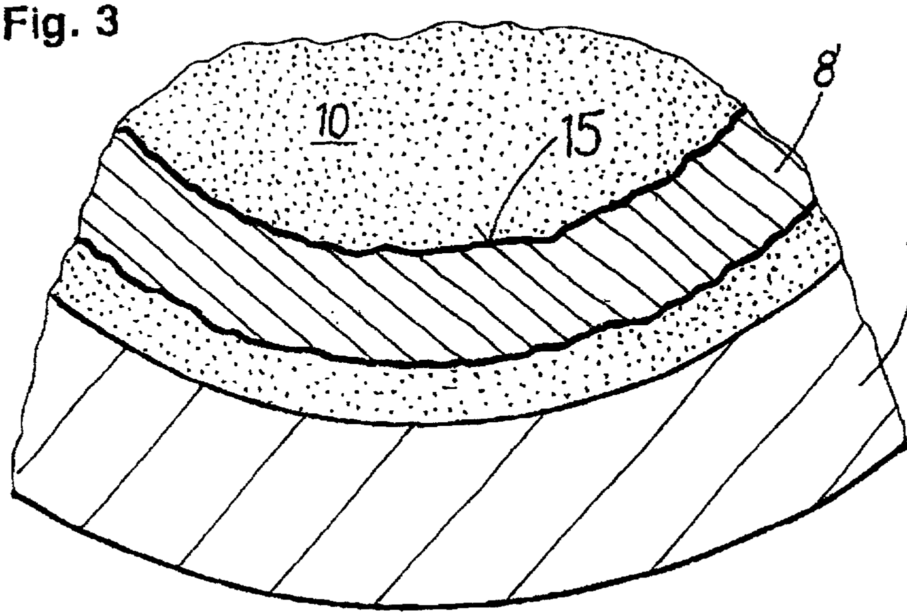


Fig. 3



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Electrically heatable glow plug or glow rod for internal combustion engines

The invention is based on an electrically heatable glow plug or a glow rod for internal combustion engines according to the precharacterizing clause of Claim 1, such as emerges as known, for example, from EP 450 185 B1.

Glow plugs are used in the combustion chamber in diesel engines for preheating purposes during cold starting or - in the form of a glow rod in the induction passage - for preheating the induction air. The glow plug or the glow rod comprises a corrosion-free, metallic casing, a heating and regulating coil and an electrically insulating, compacted powder filling. In the heating region, the heating and regulating coil consists of ferritic steel onto which a pure nickel wire is welded as a regulating resistor.

During operation, the material of the heating coil is subject to a thermal and chemical influence which may adversely affect the service life of the glow plug. These influences at least constitute essential parameters with regard to the service life of the glow plug. On account of the high operating temperatures of the heating coil and, as before, there still being oxygen in the compacted powder filling, the heating coil is subject to creeping corrosion. In specific terms, this may firstly be intercrystalline corrosion which is furthered by the growth of crystals and the tendency to form large grains in ferritic heat conductors. Secondly, at high

temperatures corrosion may occur on the free surface of the heating coil and may therefore lead to weakening of the heating-wire cross section.

Magnesium oxide is generally used as the powder filling. In order to minimize the atmospheric oxygen contained in the pores of the powder filling, the powder is very intensively compacted by the filled metal casing being upset from the outside by a concentrically acting striking tool and thereby being reduced in diameter. The powder filling is compacted particularly intensively in the region of the heating-rod tip by the metal casing being upset conically there.

The object of the invention is to improve a glow plug based on the generic type in respect of a longer service life for the heating coil.

Taking the glow plug based on the generic type as the starting point, this object is achieved according to the invention by the characterizing features of Claim 1. This is because it has been found that, during the compaction of the powder filling, the radial upsetting of the casing pipe also causes severe mechanical stress on the wire of the heating coil and on the wire of the regulating coil and in the process causes said wire to be unintentionally damaged at the outset, for example due to notches, depressions or the like, i.e. causes its cross section to be constricted locally. On account of the increase in hardness of the coil on its surface, in particular by nitriding, the coil is able to withstand the mechanical stress during compaction of the powder filling without being significantly damaged at the outset.

Expedient refinements of the invention can be gathered

from the subclaims; the invention is also explained in more detail below with reference to an exemplary embodiment which is illustrated in the drawing, in which:

Fig. 1 shows a longitudinal section through a glow plug,

Fig. 2 shows an enlarged illustration of the detail II from Figure 1, and

Fig. 3 shows a cross section through a conventional glow plug in the region of the detail II where the surface of the coil has been damaged at the outset by the mechanical stress during compaction of the powder filling.

In diesel engines, glow plugs are used in the combustion chamber for preheating during cold starting or - as a rod-shaped flame glow plug or flame system in the air inlet passage - for preheating the air. The exemplary embodiment of a glow plug which is illustrated in Figure 1 has a glow pipe 5 which is secured in a plug body 1 and is connected thereto in an electrically conductive manner. The casing of the glow pipe generally consists of a nickel-rich iron alloy or of a corrosion-free alloy based on nickel, for example Inconel 601, and is as a rule electrically connected as an earth pole, i.e. negatively. This electric earth connection comes about via the screw-in thread 7 and/or by the cone 7a at the lower end of the plug body 1.

A heating coil 8 having a regulating coil 9 which is welded to it via a connecting weld 11, and an electrically insulating, compacted powder filling 10 are arranged in the glow pipe. This powder filling has a

number of functions, particularly in the compacted state: first of all, it ensures that the heating coil (8) and regulating coil (9) are accommodated and fixed in position within the glow pipe and are held in an electrically insulated manner. The compacted powder means that the heat produced in the heating coil 8 is inevitably passed on as readily as possible to the casing of the glow pipe. In addition, the compressing of the powder is intended to eliminate to the greatest possible extent any air pockets, in particular a certain amount of residual oxygen. This requires a particularly intensive compaction of the powder, particularly in the region of the heating coil 8.

In the heating region (heating coil 8), the heating and regulating coil 8, 9 consists of a ferritic steel, for example of an iron-chromium-aluminium alloy having 17 to 22% chromium and 3 to 7% aluminium; a frequently used alloy is Kantal AF CrAl225. A coiled wire (regulating coil 9) made of pure nickel, which has the function of a regulating resistor, is welded (connecting weld 11) onto a heating coil of this type. The heating coil 8 is connected to the glow pipe in the tip of the glow pipe via a sealing weld 12.

The other end of the regulating coil 9 is connected to a connecting bolt 2 which is embedded in an insulating washer 4, is electrically insulated and is led out of the plug body 1 in a sealed manner via a seal 6. The connecting bolt is connected via a nut 3, which brings a cable lug securely into contact with the connecting bolt, to the plus pole of a current source. In addition, the connecting bolt 2 is sealed at the upper, open end of the glow pipe by a soft, insulating seal 6' which is intended to reliably prevent atmospheric oxygen from penetrating

into the compressed powder filling.

In general, magnesium oxide is used as the powder filling 10. In order to compact the powder filling - as described, the filled glow pipe is upset radially from the outside by a concentrically acting striking tool and is thereby reduced in diameter, it also being possible for a conical profile to be achieved. The powder filling is particularly intensively compacted especially in the region of the glow-pipe tip by the metal casing there being upset radially in a particularly severe manner.

On account of the intense compaction of the powder filling, the entire coil 8, 9, but in particular the heating coil 8, is severely stressed mechanically. During the radial upsetting of the glow pipe 5 not only is its casing plastically deformed, but so too are the coils 8 and 9 mounted in it. The compacting and compacted powder filling 10 also transmits actions of force from the striking tools acting from the outside isostatically to the turns of the heating and regulating coils 8 and 9 and reduces the diameters thereof to an appropriate extent during this process. Since, however, the powder filling is not completely homogeneous, but is subject to certain unevennesses, the forces exerted on the coils via the powder filling differ in size locally in accordance with the dispersion of the powder density.

In the case of untreated coils, this leads to a locally differing plastic upsetting of the coils. The differing upsetting for its part causes a stochastically pitted surface of the coils 8', as is shown in Figure 3 using the example of a conventional design of a glow plug together with an untreated coil 8'. Even when new, this coil has a pitted surface 15 after compaction of the

powder. According to the findings of the invention, a certain amount of damage from the outset is to be found in this surface pitting. This is because stochastic pitting of this type may result in local cross-sectional constrictions of the conductor cross section of the coil. This local cross-sectional constriction in turn leads to a local increase in the electrical resistance and therefore to a locally more severe heating of the coil during operation. This means that the thermal and chemical ageing processes progress more rapidly at this point, because of the higher temperature level, than at other points. Such a constriction, which is initially only small and is caused by pitting, of the conductor cross section of the coil can therefore be a determining factor in the service life, i.e. can be a factor shortening the service life.

The invention intends to increase the service life of the coils, in particular the heating coil 8 which is particularly severely stressed mechanically during compaction and is also particularly severely stressed thermally during operation. In order to increase the service life, according to the invention the electrically conductive coils 8, 9 but at least the heating coil 8 which is particularly at risk, are surface-hardened. In specific terms, a diffusion treatment, such as nitriding, is advantageously recommended, said treatment leading, through the formation of nitride in the diffusion zone, to an increase in the hardness, and as a result of the diffusion processes produces a gradual transition from the hardened edge zone to the soft core. This diffusion zone 13 of the coils 8, 9 expediently has a depth t of approximately 5 to 10 μm.

Although the coils are hardened merely in an edge layer

13 near to the surface, they nonetheless remain plastically deformable as a whole. On the other hand, pronounced pitting of the wire surface during radial compaction of the powder filling is avoided by the hardening of the edge layer. Even after the compaction of the powder filling, the coils have a smooth surface 14. As a result, mechanical damage at the outset to the conductor wire is avoided. The consequence is a longer service-life expectation for the conductor and therefore for the entire glow plug.

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Patent claims

1. Electrically heatable glow plug or glow rod for internal combustion engines, having a corrosion-resistant glow pipe which is closed at the end and contains a filling of electrically non-conductive, compacted powder in which an electrically conductive coil is embedded, characterized in that the electrically conductive coil (8, 9) is surface-hardened.

2. Glow plug or glow rod according to Claim 1, characterized in that at least the heating coil (8) is surface-hardened.

3. Glow plug or glow rod according to Claim 1, characterized in that the electrically conductive coil (8, 9) is surface-hardened, at least over part of its longitudinal extent, by a diffusion treatment, in particular by nitriding.

4. Glow plug or glow rod according to Claim 3, characterized in that the hard diffusion zone (13) of the electrically conductive coil (8, 9) has a depth (t) of approximately 5 to 10 μm.

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Abstract

The invention relates to an electrically heatable glow plug or a glow rod for internal combustion engines. Said glow plug has a corrosion-resistant glow pipe which is closed at the end and contains a filling of electrically non-conductive, compacted powder in which an electrically conductive coil is embedded. In order to improve the glow plug or the glow rod in respect of a longer service life for the heating coil, according to the invention the electrically conductive coil is surface-hardened, at least over part of its longitudinal extent, preferably in the region of the heating coil, in particular is nitride-hardened by a diffusion treatment. As a result, the coil can withstand the mechanical stress during the compaction process without being damaged at the outset.

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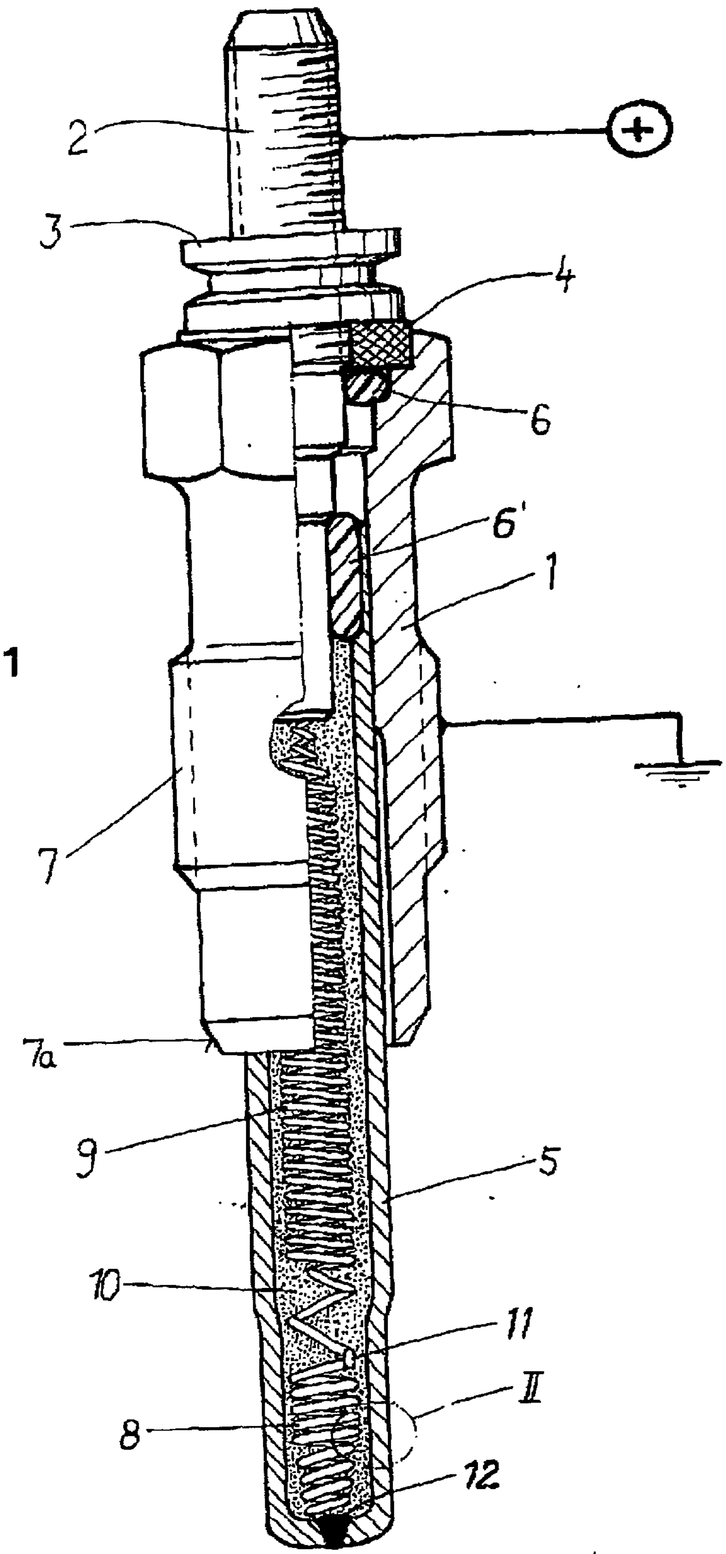

Fig. 1

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Fig. 2

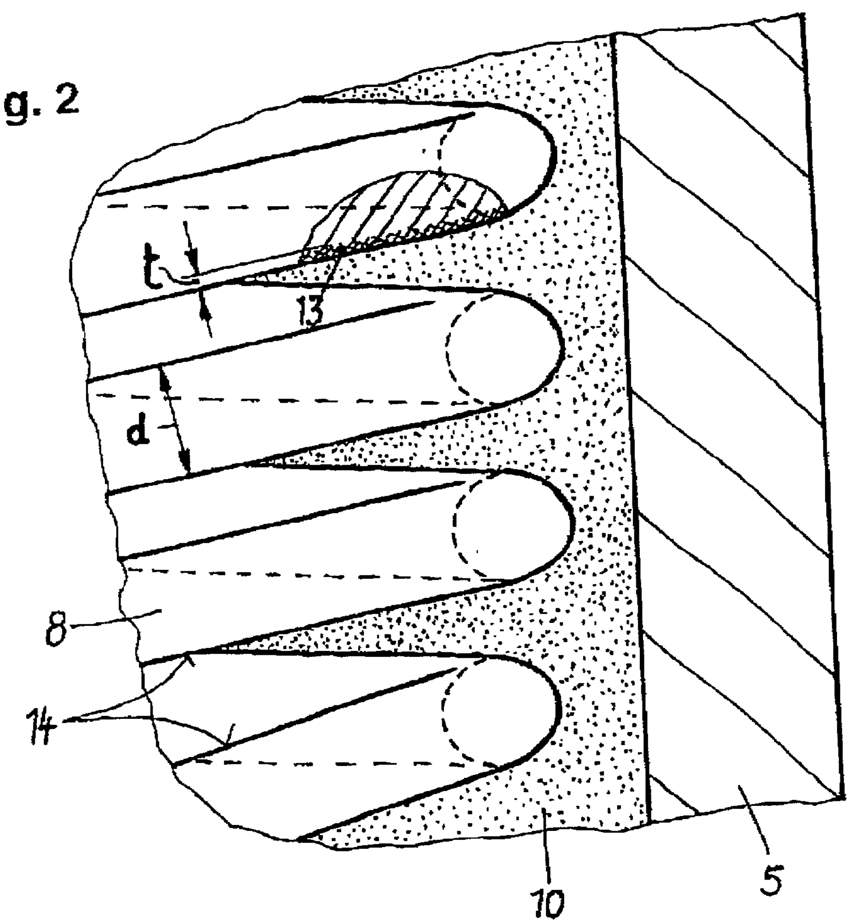
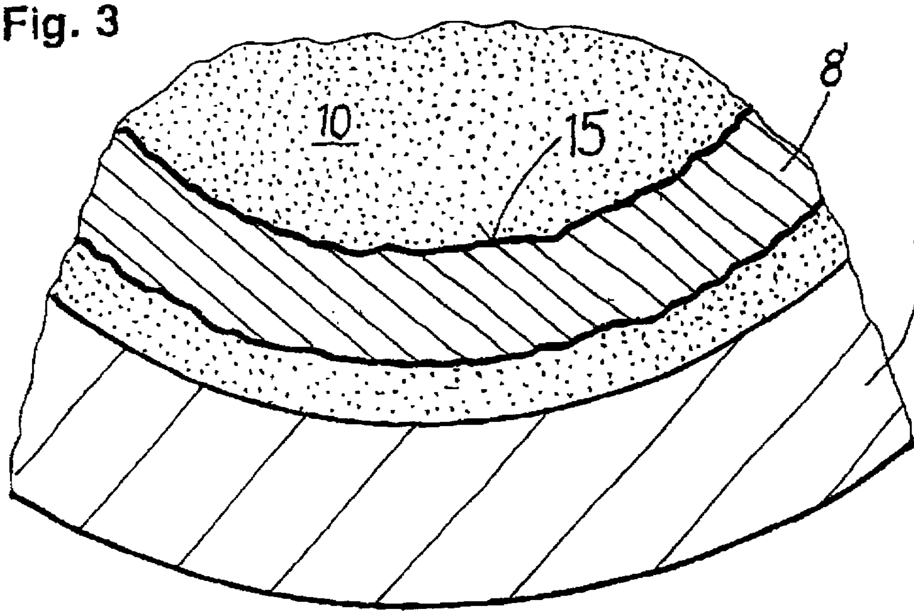


Fig. 3



COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (includes Reference to PCT International Applications)	ATTORNEY'S DOCKET NUMBER **225/50746**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

ELECTRICALLY HEATABLE GLOW PLUG OR GLOW ROD FOR INTERNAL COMBUSTION ENGINES AND METHOD OF MAKING SAME

the specification of which (check only one item below):

[ ] is attached hereto.

[ ] was filed as United States application
Serial No.
on
And was amended
on ______________ (if applicable).

[X] was filed as PCT international application
Number **PCT/EP00/04521**
on **19 May 2000**
and was amended under PCT Article 19
on ____________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations. §1.56(a).

I hereby claim foreign priority benefits under Title 35, United State Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY (if PCT indicate PCT)	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Germany	**199 28 037.1**	**18 June 1999**	[X] Yes [ ] No
			[ ] Yes [ ] No
			[ ] Yes [ ] No
			[ ] Yes [ ] No
			[ ] Yes [ ] No

Combined Declaration For Patent Application and Power of Attorney (Continued) (includes Reference to PCT international Applications	ATTORNEY'S DOCKET NUMBER 225/50746

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application(s) and the national of PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120

U.S. APPLICATIONS			STATUS (*Check one*)		
U.S. APPLICATION NUMBER	U.S. FILING DATE		PATENTED	PENDING	ABANDONED
PCT APPLICATIONS DESIGNATING THE U.S.					
PCT APPLICATION NO	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (IF ANY)			

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (List name and registration number)

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203	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
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	POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE & ZIP CODE/COUNTRY

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true: and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SIGNATURE OF INVENTOR 201	SIGNATURE OF INVENTOR 202	SIGNATURE OF INVENTOR 203
Klaus Gessner	Roland Klak	
DATE 21.3.2002	Date 27.03.2002	DATE